REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*
11-28-2011

2. REPORT TYPE
Final Report

3. DATES COVERED *(From - To)*
07/01/2008-06/30/2011

4. TITLE AND SUBTITLE
High Transition Temperature Quantum Interference Filters

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-08-1-0305

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Suite 325
Arlington, VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-OSR-VA-TR-2012-0262

12. DISTRIBUTION / AVAILABILITY STATEMENT
Public distribution/availability

13. SUPPLEMENTARY NOTES

14. ABSTRACT
We have fabricated and tested large scale arrays of Josephson junctions. Some devices have as many as 150,000 junctions in a single device. To aid in device design we have also developed a numerical simulation program in matlab to simulate voltage field characteristics for these arrays. Our numerical simulation code supports the modeling of 2 dimensional array structures and takes into account mutual interactions between all of the squids in the array. The results are in excellent agreement with our experimental measurements. We have also performed measurements of the critical current noise in our Josephson junctions and have been testing arrays in flux locked loops.

15. SUBJECT TERMS
Superconductivity, SQUID arrays

16. SECURITY CLASSIFICATION OF: Unclassified			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*

High Transition Temperature Superconducting Quantum Interference Filters
FA 9550-08-1-0305 Final Report: July 1, 2008 - June 30, 2011

R.C. Dynes and S.A. Cybart

Abstract:

We have fabricated and tested large scale arrays of Josephson junctions. Some devices have as many as 150,000 junctions in a single device. To aid in device design we have also developed a numerical simulation program in Matlab to simulate voltage magnetic field characteristics for these arrays. Our numerical simulation code supports the modeling of 2 dimensional array structures and takes into account mutual interactions between all of the squids in the array. The results are in excellent agreement with our experimental measurements. We have also performed measurements of the critical current noise in our Josephson junctions and have been testing arrays in flux locked loops.

Narrative:

Arrays of Josephson junctions or SQUIDs are of great interest for communication electronics because sensors built from them can have high-linearity, wide bandwidth and a large dynamic range. These sensors detect the magnetic field component of an incoming signal opposed to the electric field component. Quality devices have been demonstrated in low temperature superconductors but the cooling requirements to achieve 4K, exceed the size weight and power for most practical applications. Therefore our group has been investigating arrays fabricated from YBCO that can operate at 77K.

We built two different configurations of array for this grant. The first contained a series array of 500 SQUIDs embedded into a coplanar wave guide,[1] and the second was a 2D array with tens of thousands of junctions built into a superconducting microstrip.[2] Measurements of these devices revealed that when the SQUIDs are placed in close proximity with one another mutual interactions between them significantly reduce the modulation voltage and alter linearity.[3] We were able to confirm this by developing computer simulation software that solves the differential equations for all of the junctions in the array simultaneously to generate voltage- magnetic field characteristics.[4] The results obtained from our simulations are in excellent agreement with experimental measurements for many different 2D array configurations. Using our simulation program we have developed new array geometries optimized for maximum voltage modulation and transfer function linearity. [5]

We have also improved our fabrication process by eliminating an initial photolithography patterning step and moving to an all electron beam lithography process. The new process reduces the turn-around time by a factor of 2. We have also improved our reactive ion etch nanopatterning of implantation masks [6] to accommodate higher implant energies. In addition we performed an aging and stability study on older Josephson junctions fabricated using our technique. We found that these junctions are very robust and that their properties namely Ic and Rn have changed very little over the course of 7 years.

The results obtained under this grant will greatly help this technology move forward in to the future. This grant has supported 1 postdoc, 2 graduate students, and 6 undergraduate student researchers.

Publications:

[1] S. A. Cybart, S. M. Wu, S. M. Anton, I. Siddiqi, J. Clarke and R. C. Dynes, *"Incommensurate arrays of high-transition temperature SQUIDS from ion damage Josephson junctions"*, Appl. Phys. Lett., vol 93, 182502 2008.

[2] S. A. Cybart, S. M. Anton, S. M. Wu, J. Clarke, and R. C. Dynes, *"Very large scale integration of nanopatterned* $YBa_2Cu_3O_{7-\delta}$ *Josephson junctions in a two-dimensional array"*, Nano Lett., nl901785j, 2009.

[3] S. A. Cybart, S. M. Anton, J. A. Drisko, T. Dalilouch, J. M. Parker, S. M. Wu, E. Cho, J. Clarke, and R. C. Dynes, *"Measurements and simulations of two dimensional arrays of SQUIDs from ion damage Josephson junctions"*, in preparation.

[4] T. Dalilouch, S. A. Cybart, S. M. Anton, J. Clarke, and R. C. Dynes, *"Comparison of numerically simulated transfer functions for two-dimensional Josephson arrays with different geometries"*, in preparation.

[5] S. M. Anton, S. A. Cybart, R. C. Dynes, *"Algorithm for designing SQUID arrays with high linearity"* in preparation.

[6] S. A. Cybart, E. Ulin-Avila, and R. C. Dynes, *"Angled reactive ion etching of high-aspect-ratio nanostructures"*, in preparation.

[7] E. Y. Cho, T. J. Wong, S. A. Cybart, Ke Chen, R. C. Dynes, *"Long-term stability of high-transition temperature Josephson junctions prepared from ion irradiation"*, in preparation

[8] S. M. Wu, S. A. Cybart, P. Yu, M. D. Rossel, J. X. Zhang, R. Ramesh and R. C. Dynes, *"Reversible control of exchange bias in a multiferroic field effect device"*, Nature Materials., nmat2803, 2010.